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**OPERATIONAL DEAD AIR SPACE AND  
CROSS-CONTAMINATION TESTING  
OF THE CHEMICALLY PROTECTED DEPLOYABLE  
MEDICAL SYSTEMS (CP DEPMEDS)**

**A.T. Seitzinger  
S.B. Sapperstein**

**RESEARCH AND TECHNOLOGY DIRECTORATE**

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**E.R. Knoebel  
R.S. Grieb**

**GEO-CENTERS, INC.  
Fort Washington, MD 20744**

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## PREFACE

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# **OPERATIONAL DEAD AIR SPACE AND CROSS-CONTAMINATION TESTING OF THE CHEMICALLY PROTECTED DEPLOYABLE MEDICAL SYSTEMS (CP DEPMEDS)**

## **1. INTRODUCTION**

### **1.1. Purpose.**

This report documents the results and findings of dead air space testing conducted on an assembled representative Chemically Protected Deployable Medical System (CP DEPMEDS). The objective of this test was to identify the location of any dead air areas within the CP DEPMEDS. These dead air spaces present potential vapor accumulation locations, and threaten the collective protection performance of the CP DEPMEDS in a Nuclear, Biological, or Chemical (NBC) warfare environment. A subsequent cross-contamination test was also conducted. This test was used to check the integrity of each unit of the CP DEPMEDS in remaining uncontaminated in the event that another unit becomes contaminated.

### **1.2. Background.**

The CP DEPMEDS consist of various size shelters approximately 20 ft. x 20 ft. x 10 ft. to 64 ft. x 20 ft. x 10 ft. The shelters were overpressurized to chemically protect the inside environment and connected to each other by viaducts (see figure 1). Designed by the U.S. Army Natick Research, Development and Engineering Center (Natick), the shelters provide a clean air-conditioned atmosphere to treat personnel wounded in an NBC warfare environment.

### **1.3. Test Theory / Methodology.**

The approach for determining the locations of dead air spaces within the CP DEPMEDS is to first use a Nutem Limited, NPL-type, smoke generator to identify potential dead air spaces. By observing air flow patterns in each shelter unit and connecting viaducts with the smoke, potential dead air spaces are recorded. Close attention is given to restricted air-flow areas, such as the viaducts and the air spaces between the interior lining and the shelter wall, where applicable.

Potential identified dead air spaces will be confirmed as dead air areas by releasing gaseous sulfur hexafluoride (SF<sub>6</sub>), a chemical agent simulant vapor, and monitoring the concentration of SF<sub>6</sub> in these spaces using miniature infrared air analyzers (MIRAN-1A). If the monitored potential dead air spot SF<sub>6</sub> concentration increases and subsequently decreases substantially, the area is not considered a dead air space.

After dead air space testing is completed, a cross contamination test will be performed. To perform this test the unit which is most likely to be contaminated in an NBC warfare environment (the PPU) is contaminated to a concentration on the order of 10000 ppm with SF<sub>6</sub>. Contamination in the other units of the CP DEPMEDS is monitored using sequential samplers to collect air samples for measurement of their concentrations of SF<sub>6</sub> using an

electron capture gas chromatograph (ECGC). If concentration of SF<sub>6</sub> in other units of the CP DEPMEDS is above 3.5 - 7.5 mg/m<sup>3</sup> or 2.96 - 6.35 ppm (in a 10 minute exposure period for nerve agent sarin (GB))<sup>1</sup>, those units are considered contaminated.

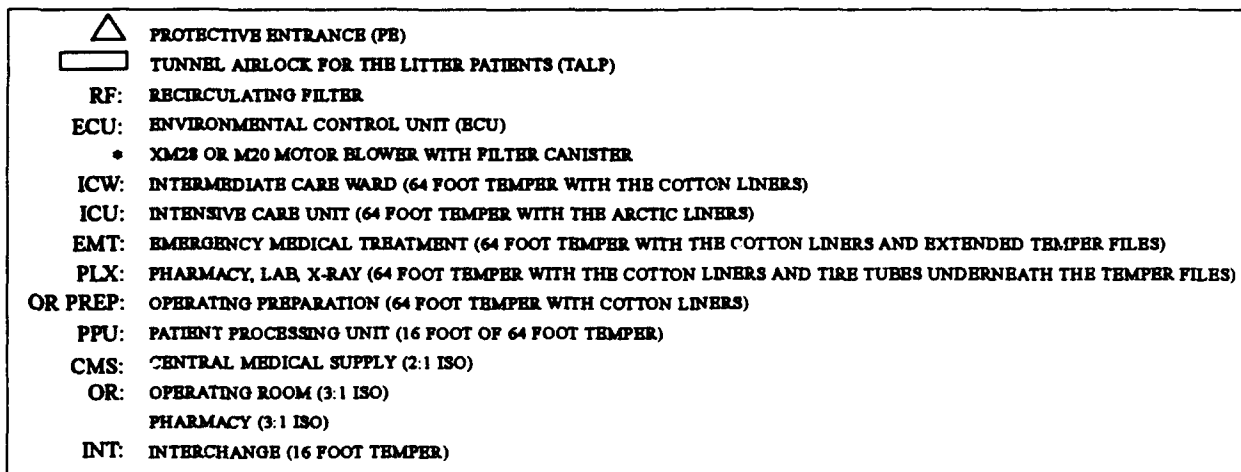
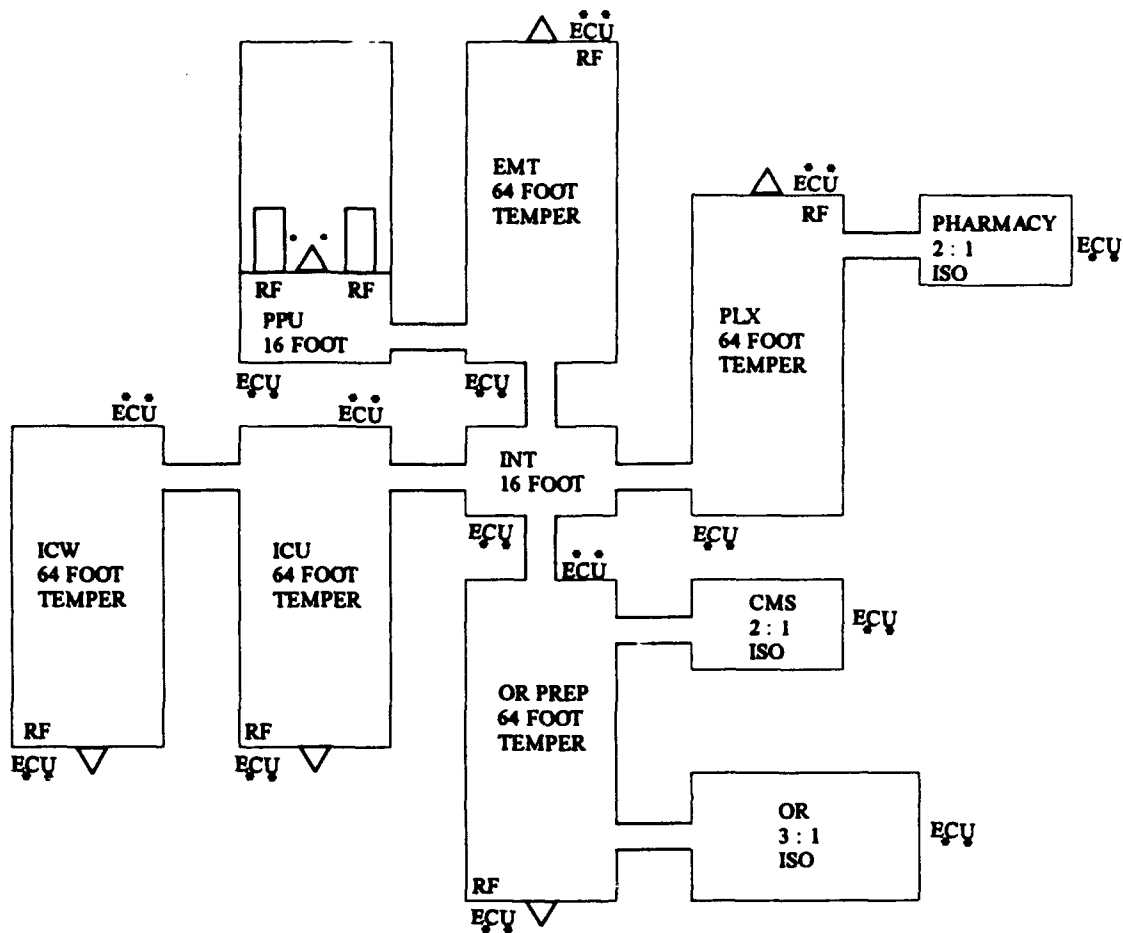
These tests are to be carried out while the CP DEPMEDS is operating under normal field conditions (i.e., ventilation system running at designed air flow rate and overpressure).

## **2. TEST SET-UP / PROCEDURE**

### **2.1. CP DEPMEDS Test Set-up.**

The test site for these field trials was Ft. Indiantown Gap, PA, from the 10<sup>th</sup> of August 1992 through the 14<sup>th</sup> of August 1992. The test CP DEPMEDS, consisting of ten shelter units, was a complete field system. The shelters assembled were in the correct configuration and ventilated by chemically hardened C100 air handling (A/C) units and had XM28 personnel entrances (PE) (Figure 1.). The shelters were ventilated with an input volumetric flow rate ranging from 400 - 800 cubic feet per minute (CFM), which produced a designed overpressure of 0.5 inchs of water (in. WG). All of the shelter units except the PPU were installed with beige cotton interior liners. The liners were attached to the shelter XM28 liner and support pipes by strings, and were designed to insulate the shelter's interior atmosphere from the shelter walls. Extreme care was taken when observing the smoke patterns in order not to disrupt the established flow patterns by not disturbing the liners.

## CP DEPMEDS TEST COMPLEX



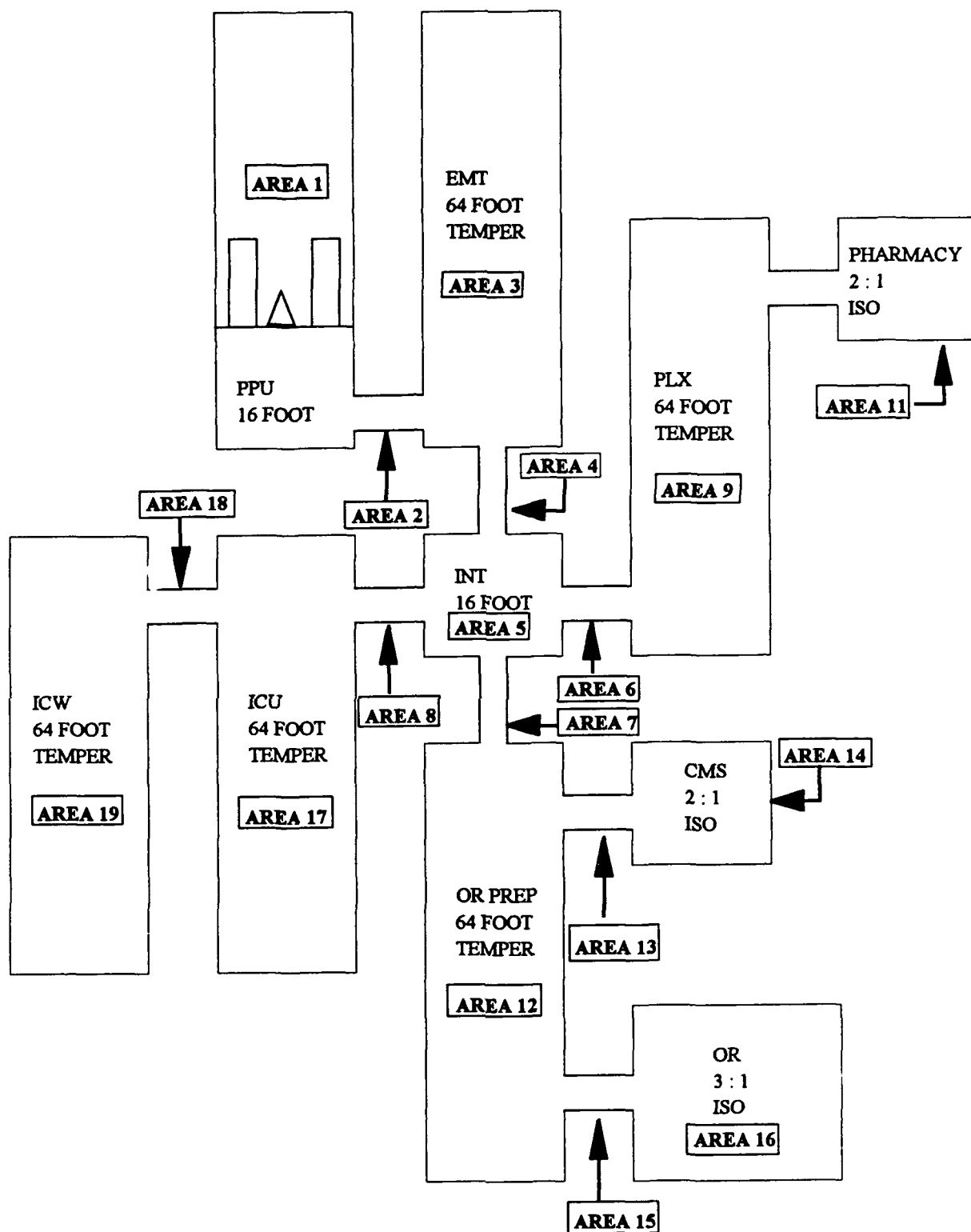
**Figure 1. CP DEPMEDS Complex Set-Up**

## **2.2. Air Flow Pattern Observation Set-up / Procedure.**

The most critical element for this test was the smoke generator. A ribbon of smoke was produced when the generator fuel pump speed was set to 5, and the heater voltage control was set to 23. The oil used by the generator to produce the smoke was poly-ethylene glycol. Figure 2 shows the general CP DEPMEDS air flow observation points conducted throughout the system.

The procedure for observing air flow patterns in the CP DEPMEDS with the smoke generator was as follows:

1. Set the smoke generator controls
  - Fuel pump speed = 5
  - Heater voltage = 23
2. Turn-on pump
3. Let oil drip from vaporization probe (give about 2 to 3 minutes for oil to run through small fuel line to probe tip)
4. Turn-on power to probe once oil starts to drip from tip
5. Allow smoke to stabilize before bringing probe over to area of interest
6. Place probe initially close to the floor and slowly raise the probe up to the shelter ceiling
7. Observe movement of smoke plume
8. Move probe to next area of interest and repeat steps 6 and 7 until all areas have been tested
9. Turn-off power to vaporization probe
10. Turn-off oil pump



**Figure 2. Location of Areas for Air Flow Pattern Observations**

### 2.3. Cross contamination Test Set-up / Procedure.

Sequential samplers are set up in the Emergency Medical Treatment Unit, Pharmacy, Interchange, Intensive Care Unit, and Operating Preparation Unit (Figure 3.). At test start, the sequential samplers take two background samples, one at 5 minutes and the other at 10 minutes. Using the Patient Processing Unit as the unit most likely to be contaminated, SF<sub>6</sub> is dispensed through the ECU for 10 minutes until a 10000 ppm contamination level is reached. The quantity of SF<sub>6</sub> dispensed is monitored using a MIRAN-1A. When the desired level of SF<sub>6</sub> is reached, the discharge is terminated. While the SF<sub>6</sub> is being dispensed, the sequential samplers collect air samples every five minutes up to 40 minutes after the termination of dispensed SF<sub>6</sub>. Samples are analyzed later by an electron capture gas chromatograph.

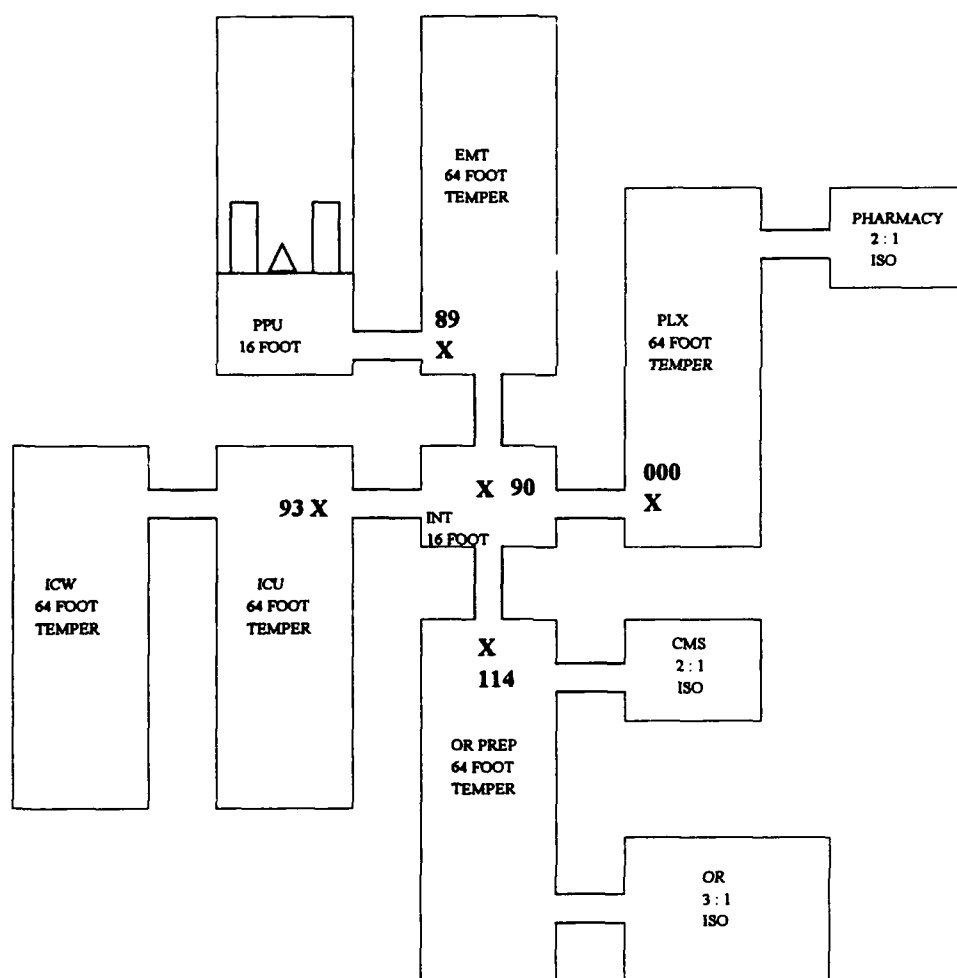


Figure 3. Location of Sequential Samplers for the Cross Contamination Test

### 3. TEST RESULTS

#### 3.1. Air Flow Pattern Observations.

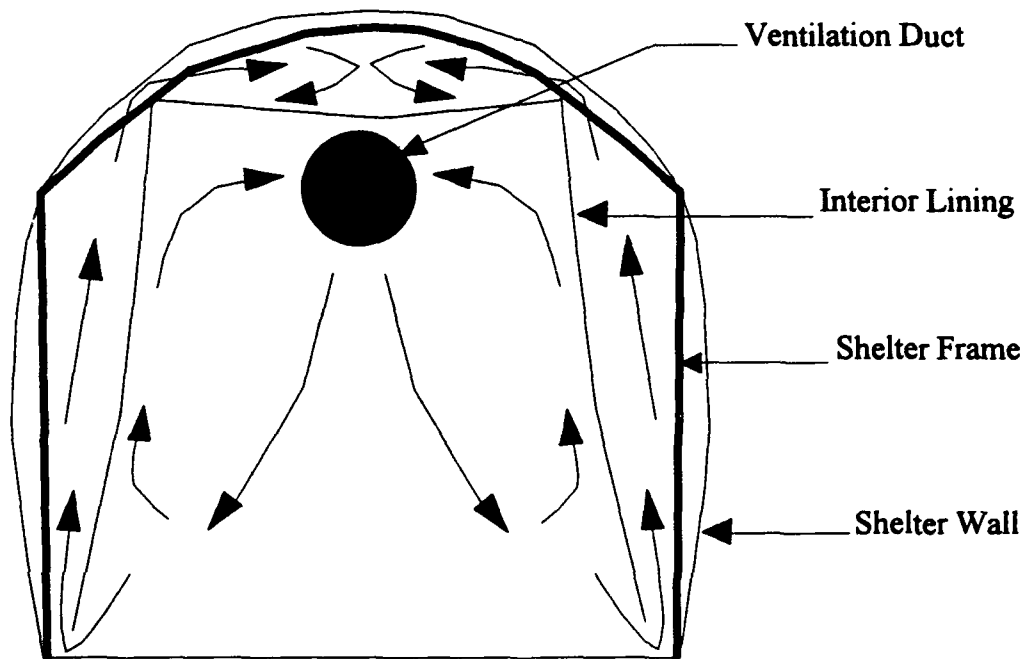
##### Test Conditions (Interior):

Date: 11 August 1992  
Dry Bulb Temperature: 79.9°F  
Wet Bulb Temperature: 59.0°F  
Barometric Pressure: 29.42 in. Hg  
Relative Humidity: 29%

The following comments and figures correspond to the areas labeled in figure 2.

##### 1. Patient Processing Unit (PPU)

Overpressure = 0.54 in. WG at PE  
No potential dead air spaces observed



**Figure 4. General Air Flow Pattern for a CP DEPMEDS Shelter Unit With an Interior Liner (Cross-Section View)**

2. Viaduct from PPU to EMT  
No potential dead air spaces observed

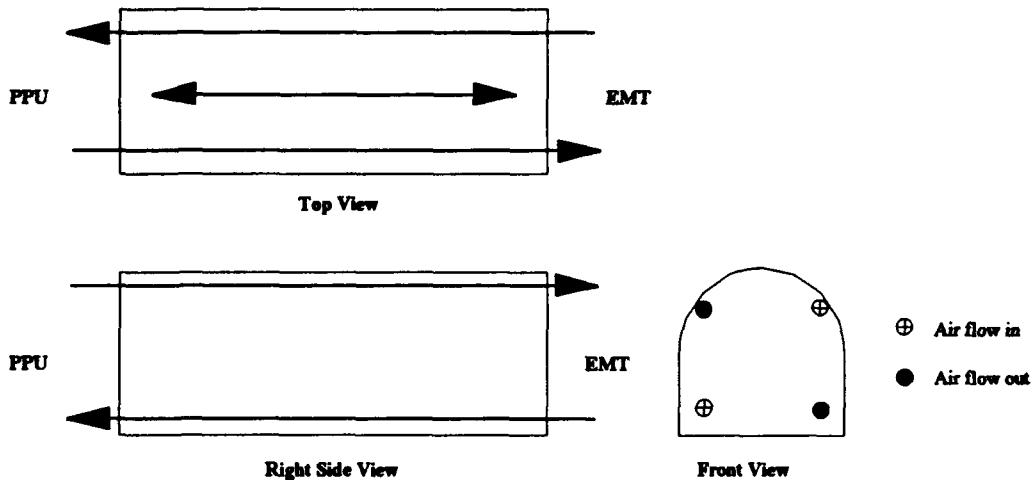


Figure 5. Observed Air Flow Pattern for PPU to EMT Viaduct

3. Emergency Medical Treatment (EMT)  
Overpressure = 0.52 in. WG at PE  
No potential dead air spaces observed.
4. Viaduct from EMT to INT  
No potential dead air spaces observed.  
Circulating pattern for area 4 was not the same as in area 2. Air movement was slow but predominately in the INT direction.
5. Interchange (INT)  
No potential dead air spaces observed.
6. Viaduct from INT to PLX  
No potential dead air spaces observed.  
Air pattern was well-mixed.
7. Viaduct from INT to OR PREP  
No potential dead air spaces observed.  
Air pattern was well-mixed.
8. Viaduct from INT to ICU  
No potential dead air spaces observed.  
Air pattern was well-mixed.



Date: 12 August 1992  
Dry Bulb Temperature: 64°F  
Wet Bulb Temperature: 60°F  
Barometric Pressure: 29.58 in. Hg  
Relative Humidity: 80%

9. Pharmacy, Lab. and X-ray (PLX)

Overpressure = 0.53 in. WG at PE

No potential dead air spaces observed.

10. Viaduct from PLX to Pharmacy

No potential dead air spaces observed.

Air flow pattern swirls inside viaduct, but blows into the PLX and the Pharmacy at the ends of the viaduct.

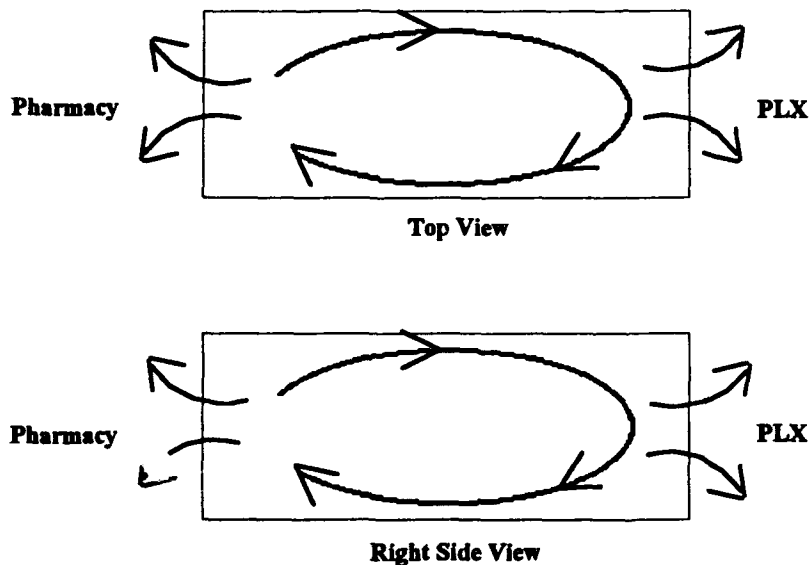


Figure 6. Observed Air Flow Pattern for Pharmacy to PLX Viaduct

11. Pharmacy

No potential dead air spaces observed.

12. Operating Room (OR) Prep

Overpressure = 0.51 in WG at PE

No potential dead air spaces observed.

13. Viaduct from OR Prep to CMS

No potential dead air spaces observed.

Air movement was slow and well-mixed (see figure 7).

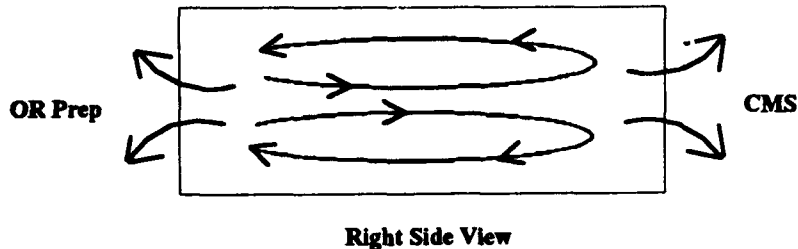


Figure 7. Observed Air Flow Pattern for OR Prep to CMS Viaduct

14. Central Medical Supply (CMS)

No potential dead air spaces observed.

15. Viaduct from OR Prep to OR

No potential dead air spaces observed.

Air movement was slow and well-mixed (see figure 7).

16. OR

No potential dead air spaces observed.

17. Intensive Care Unit (ICU)

Overpressure = 0.52 in. WG at PE

No potential dead air spaces observed.

Air movement was restricted by the insulated liner; however enough space was left between the curtains and the wall to allow for sufficient air circulation.

18. Viaduct from ICU to ICW

No potential dead air spaces observed.

Air movement was slow and well mixed (see figure 7).

19. ICW

Overpressure = 0.52 in. WG at PE

No potential dead air spaces observed.

### 3.2. Cross Contamination Test.

#### Test conditions:

|                         |                |
|-------------------------|----------------|
| Date:                   | 13 August 1992 |
| Start time:             | 0900 hrs       |
| Test background time:   | 10 min.        |
| Test dissemination time | 5 min.         |
| Test stop time          | 1000 hrs       |
| Dry bulb temperature    | 64°F           |
| Wet bulb temperature    | 60°F           |
| Barometric pressure     | 29.721 in. Hg  |
| Relative humidity       | 80%            |

#### Equipment settings:

##### Flowmeter settings:

SF<sub>6</sub>: setting = 31.3 l/min

air: 880 cu. ft. / min. in PPU

##### ECGC (S/N 0044 and S/N 0042) settings:

C-scale

1 ml loop sampling

#### Estimated challenge concentration:

$$\text{SF}_6 \text{ mass flow} = 31.3 \text{ L / min} * 6.602 \text{ g / L} = 206 \text{ g SF}_6 / \text{min}$$

$$\text{air flow} = 880 \text{ cu. ft. / min.} * 1000 \text{ L / 35.3145 cu. ft.} = 24.92 \text{ m}^3 / \text{min.}$$

$$\text{air mass} = 24.92 \text{ m}^3 / \text{min} * 1181 \text{ g / m}^3 = 29429 \text{ g / min}$$

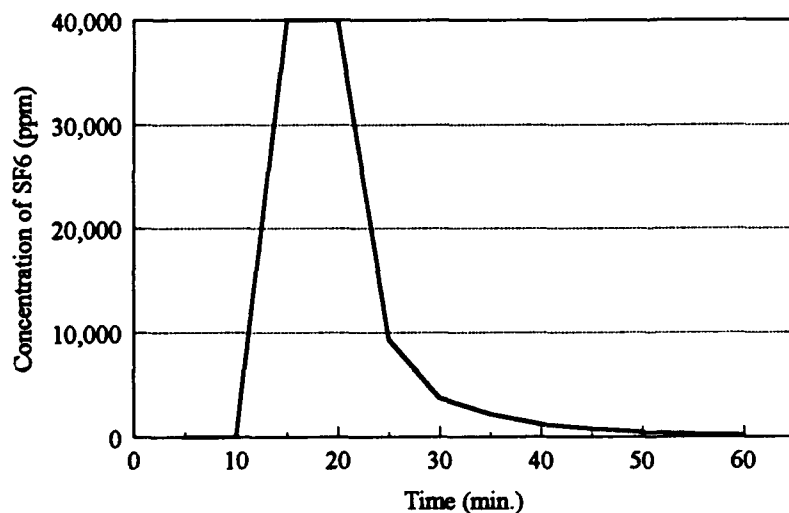
$$\text{g SF}_6 / \text{g air} = 206 / 29429 = 7000 \text{ ppm}$$

**Table 1. Miran Monitoring of SF<sub>6</sub> in PPU**

| Time (min.) | Voltage (V) | Concentration (ppm) |
|-------------|-------------|---------------------|
| 5           | 0           | 0                   |
| 10          | 0           | 0                   |
| 15          | > 1.0       | > 40134             |
| 20          | > 1.0       | > 40134             |
| 25          | .760        | 9321                |
| 30          | .640        | 3733                |
| 35          | .580        | 2208                |
| 40          | .520        | 1236                |
| 45          | .480        | 804                 |
| 50          | .440        | 507                 |
| 55          | .410        | 351                 |
| 60          | .360        | 174                 |

**Calibration equation:**  $\ln(\text{conc}) = 5.32 [\ln(\text{volt})] + 10.6$  , for volt > 0.0

## SF<sub>6</sub> Concentration in PPU vs Time



**Graph 1. SF<sub>6</sub> Concentration in PPU vs Time.**

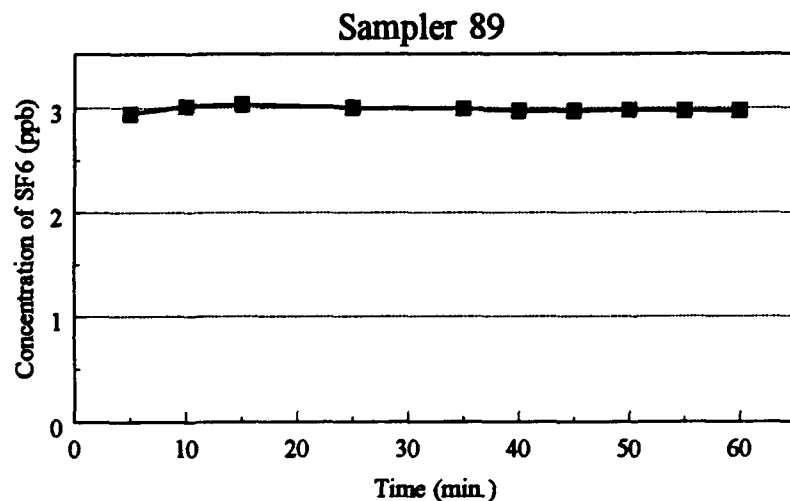
**Table 2. SF<sub>6</sub> Concentrations in EMT Using Sampler 89 and ECGC (0044)**

| Time (min.) | Response (mV) | Concentration (ppb) |
|-------------|---------------|---------------------|
| 5           | 361.9         | 2.94                |
| 10          | 372.5         | 3.01                |
| 15          | 373.2         | 3.03                |
| 20          | *failure      | ---                 |
| 25          | 369.8         | 3.00                |
| 30          | *failure      | ---                 |
| 35          | 367.4         | 2.99                |
| 40          | 365.2         | 2.97                |
| 45          | 366.2         | 2.97                |
| 50          | 367.3         | 2.98                |
| 55          | 366.5         | 2.97                |
| 60          | 366.0         | 2.97                |

\*failure represents a syringe that did not operate

Calibration equation for ECGC (S/N 0044):  $\ln(\text{conc}) = [\ln(\text{mv}) - 4.849] / .964$

## SF<sub>6</sub> Concentration in EMT vs Time



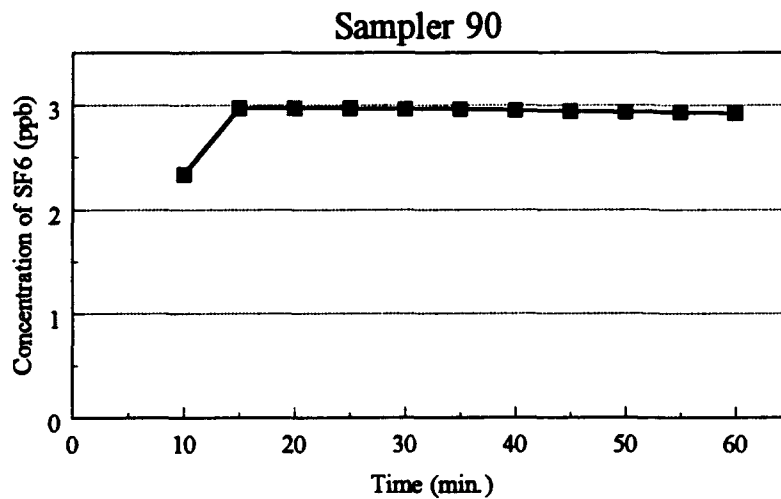
**Graph 2. SF<sub>6</sub> Concentration in EMT vs Time.**

**Table 3. SF<sub>6</sub> Concentrations in INT Using Sampler 90 and ECGC (0044)**

| Time (min.) | Response (mV) | Concentration (ppb) |
|-------------|---------------|---------------------|
| 5           | *failure      | ---                 |
| 10          | 289.1         | 2.34                |
| 15          | 364.8         | 2.97                |
| 20          | 365.9         | 2.97                |
| 25          | 365.1         | 2.97                |
| 30          | 364.3         | 2.96                |
| 35          | 364.1         | 2.96                |
| 40          | 363.6         | 2.95                |
| 45          | 362.9         | 2.94                |
| 50          | 360.6         | 2.93                |
| 55          | 360.1         | 2.93                |
| 60          | 358.0         | 2.92                |

\*failure represents a syringe that did not operate

## SF<sub>6</sub> Concentration in INT vs Time

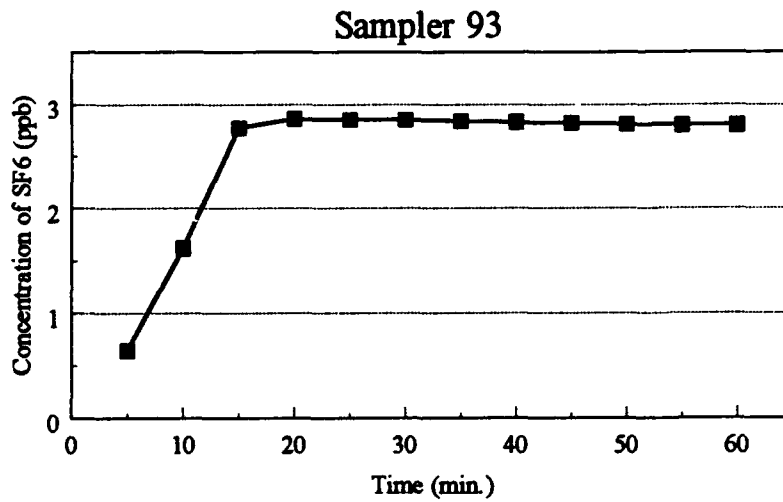


**Graph 3. SF<sub>6</sub> Concentration in INT vs Time.**

**Table 4. SF<sub>6</sub> Concentrations in ICU Using Sampler 93 and ECGC (0044)**

| Time (min.) | Response (mV) | Concentration (ppb) |
|-------------|---------------|---------------------|
| 5           | 83.45         | .644                |
| 10          | 203.4         | 1.62                |
| 15          | 342.4         | 2.77                |
| 20          | 351.4         | 2.86                |
| 25          | 350.4         | 2.85                |
| 30          | 350.3         | 2.85                |
| 35          | 349.1         | 2.84                |
| 40          | 347.9         | 2.83                |
| 45          | 346.7         | 2.82                |
| 50          | 344.6         | 2.81                |
| 55          | 342.1         | 2.80                |
| 60          | 341.4         | 2.80                |

## SF<sub>6</sub> Concentration in ICU vs Time



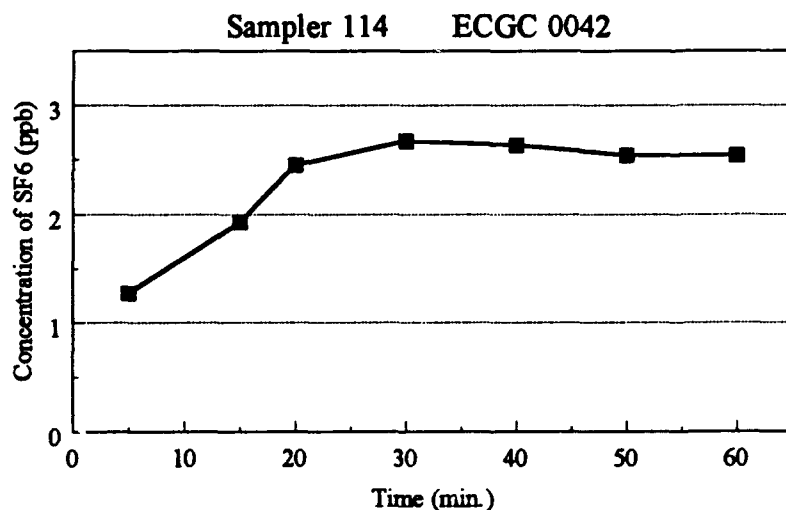
**Graph 4. SF<sub>6</sub> Concentration in ICU vs Time.**

**Table 5. SF<sub>6</sub> Concentrations in OR PREP Using Sampler 114**

| Time (min.) | ECGC (S/N) | Response (mV) | Concentration (ppb) |
|-------------|------------|---------------|---------------------|
| 5           | 0042       | 272.2         | 1.27                |
| 10          | 0044       | 6.3           | .0247               |
| 15          | 0042       | 404.6         | 1.93                |
| 20          | 0042       | 532.5         | 2.45                |
| 25          | 0044       | 328.7         | 2.67                |
| 30          | 0042       | 550.3         | 2.67                |
| 35          | 0044       | 336.1         | 2.73                |
| 40          | 0042       | 542.6         | 2.63                |
| 45          | 0044       | 325.3         | 2.64                |
| 50          | 0042       | 525.7         | 2.54                |
| 55          | 0044       | 318.1         | 2.58                |
| 60          | 0042       | 525.0         | 2.54                |

**Calibration equation for ECGC (S/N 0042)**       $\text{LN (conc)} = [\text{LN (mv)} - 5.380] / .948$

### SF<sub>6</sub> Concentration in OR PREP vs Time



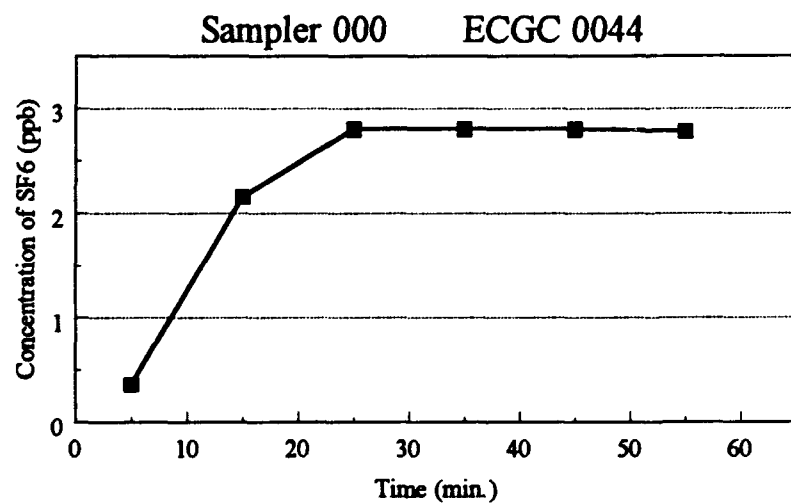
**Graph 5. SF<sub>6</sub> Concentration in OR Prep vs Time.**



**Table 6. SF<sub>6</sub> Concentrations in PLX Using Sampler 000**

| Time (min.) | ECGC (S/N) | Response (mV) | Concentration (ppb) |
|-------------|------------|---------------|---------------------|
| 5           | 0044       | 47.76         | .358                |
| 10          | 0042       | 28.2          | .120                |
| 15          | 0044       | 268.3         | 2.16                |
| 20          | 0042       | 535.3         | 2.59                |
| 25          | 0044       | 342.9         | 2.80                |
| 30          | 0042       | 533.5         | 2.58                |
| 35          | 0044       | 342.4         | 2.80                |
| 40          | 0042       | 529.7         | 2.56                |
| 45          | 0044       | 341.1         | 2.80                |
| 50          | 0042       | 527.1         | 2.55                |
| 55          | 0044       | 339.7         | 2.78                |
| 60          | 0042       | 527.5         | 2.55                |

## SF<sub>6</sub> Concentration in PLX vs Time



**Graph 6. SF<sub>6</sub> Concentration in PLX vs Time.**

#### 4. DISCUSSION

Based on the observed air flow patterns using smoke, no stagnant air spaces were located. This was the case even in restricted air flow areas, such as between the interior shelter wall and insulating liner (See figure 4). It should be noted that if the interior liners of the shelter units had been installed more securely (i.e., secured tighter to the walls and ceilings without sagging, openings between liner panels and the floor), dead air spaces might have occurred. The rather large spaces between the shelter wall and liner (in most cases large enough for a person to crawl through) and the gaps among the connected liner panels allowed air to be circulated in these restricted areas.

No cross contamination was observed in the CP DEPMEDS. A challenge  $\text{SF}_6$  contamination concentration in excess of  $4 \times 10^4$  ppm in the PPU produced net  $\text{SF}_6$  concentrations no greater than 3 ppb in the EMT, INT, PLX, ICU, and OR PREP for the hour test due to diffusion. These trace concentrations are three orders of magnitude lower than the 2.96 - 6.35 ppm concentration established for a contaminated environment. This contamination criteria was derived from the miosis level dose for GB for a 10 minute exposure time. The air flow patterns observed in the viaducts between the shelter units also indicated that no cross contamination would occur, because no significant bulk flow of the smoke could be seen going from one unit to another.

#### 5. RECOMMENDATIONS

It is highly recommended that installation guidance for the interior shelter liners specifically allow for gaps and misalignments between liners. It was observed that air was allowed to circulate between the liners and the shelter walls through these openings. Conceivably, if the liners were installed perfectly (i.e., using the Velcro strips to connect and closely secure the liners to the shelter floor and walls) no air flow would occur in the insulation barrier between the walls and interior liners. This insulation barrier would essentially be a dead air space.

### **LITERATURE CITED**

1. Chester, C. V., Technical Options for Protecting Civilians from Toxic Vapors and Gases, ORNL-TM 10423, Oak Ridge National Laboratory, Oak Ridge Tennessee, May 1988, UNCLASSIFIED Technical Manual.

2. Seitzinger, A., and Richardson, T., Operational Dead Air Space Testing of the Chemically Protected Deployable Medical Systems (CP DEPMEDS), CRDEC-TR-384, U.S. Army Armament Munitions Chemical Command, Aberdeen Proving Ground, Maryland, July 1992, UNCLASSIFIED Technical Report.

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**APPENDIX A**

**MATERIAL SAFETY DATA SHEETS**

## MATERIAL SAFETY DATA SHEET

---

Matheson Gas Products  
30 Seaview Drive  
Secaucus, New Jersey 07096  
(201) 867-4100

EMERGENCY CONTACT:  
Chemtrec 1-800-424-9300

---

### SUBSTANCE IDENTIFICATION

CAS-NUMBER 2551-62-4

SUBSTANCE: Sulfur Hexafluoride

TRADE NAMES/SYNONYMS:

Sulfur Fluoride; Sulphur Hexafluoride; Elegas; STCC 4904575; UN 1080; MAT22300

CHEMICAL FAMILY:

Inorganic gas

MOLECULAR FORMULA: F<sub>6</sub>-S

MOLECULAR WEIGHT: 146.06

CERCLA RATINGS (SCALE 0-3): HEALTH = 1 FIRE = 0 REACTIVITY = 0 PERSISTENCE = 0

NFPA RATINGS (SCALE 0-4): HEALTH = 1 FIRE = 0 REACTIVITY = 0

---

### COMPONENTS AND CONTAMINANTS

COMPONENT: Sulfur Hexafluoride  
CAS# 2551-62-4

PERCENT: 100

OTHER CONTAMINANTS: None

EXPOSURE LIMITS:

SULFUR HEXAFLUORIDE:

1000 PPM OSHA TWA

1000 PPM (6000 mg/m<sup>3</sup>) ACGIH TWA

---

### PHYSICAL DATA

DESCRIPTION: Colorless, Oderless gas.

BOILING POINT: -82.8 F (-63.8 C) (SUBLIMES)

MELTING POINT: -58.9 F (-50.5 C)

SPECIFIC GRAVITY: 1.68

VAPOR PRESSURE: 16,548 mm HG @ 20 C

SOLUBILITY IN WATER: Slightly soluble

VAPOR DENSITY: 5.1

SOLVENT SOLUBILITY: Soluble in Alchol, Ether, Potassium Hydroxide, Transformer Oil;  
Insoluble in Hydrochloric Acid, Ammonia

---

---

## FIRE AND EXPLOSION DATA

### FIRE AND EXPLOSION HAZARD:

Negligible fire hazard when exposed to heat or flame..

### FIREFIGHTING MEDIA:

Dry chemical, Carbon Dioxide or Halon  
(1987 Emergency Response Guidebook, DOT P 5800.4).

For larger fires, use water spray, fog of standard foam  
(1987 Emergency Response Guidebook, DOT P 5800.4).

### FIREFIGHTING:

Move container from fire area if possible. Stay away from storage tank ends. Cool fire-exposed containers with water from the side until well after the fire is out. Withdraw immediately if rising sound from venting safety device or discoloration of storage tanks due to fire (1987 Emergency Response Guidebook, DOT P 5800.4, Guide page 12).

Use agents suitable for type of fire. Cool containers with flooding amounts of water, apply from as far a distance as possible. Avoid breathing toxic vapors, keep upwind.

---

## TRANSPORTATION DATA

DEPARTMENT OF TRANSPORTATION HAZARD CLASSIFICATION 49 CFR 172.101:  
Nonflammable gas

DEPARTMENT OF TRANSPORTATION LABELING REQUIREMENTS 49 CFR 172.101 AND  
SUBPART E:  
Nonflammable gas

DEPARTMENT OF TRANSPORTATION PACKAGING REQUIREMENTS: 49 CFR 173.304  
EXCEPTIONS: 49 CFR 173.306

---

## TOXICITY

### SULFUR HEXAFLUORIDE:

5790 Mg/Kg Intravenous - Rabbit LD50; Carcinogen status: none.  
Sulfur hexafluoride is a simple asphyxiant.

---

## HEALTH EFFECTS AND FIRST AID

### INHALATION:

#### SULFUR HEXAFLUORIDE:

##### Asphyxiant.

Acute exposure - In man, inhalation of 80% sulfur hexafluoride and 20% oxygen for 5 minutes has produced peripheral tingling and a mild excitement stage with some altered hearing in most subjects. At high concentrations, sulfur hexafluoride acts as a simple asphyxiant as a result of the displacement of air by the heavier gas. In sudden and acute asphyxia, Unconsciousness is immediate. When asphyxia develops

slowly, increased volume of breathing, accelerated pulse rate, muscular incoordination, faulty judgement, emotional instability, fatigue, fainting, nausea, vomiting, disorientation, and respiration in gasps may be present. Impure forms may contain toxic and corrosive low sulfur fluorides which on contact with water form highly toxic and corrosive hydrogen fluoride.

Chronic exposure - Fifty rats exposed to an atmosphere containing 80% sulfur hexafluoride for periods of 16 to 24 hours showed no effects from the exposure. A concentration of 170,000 ppm for 18 hours was not lethal to any of the rats tested.

First aid - Remove from exposure area to fresh air immediately. If breathing has stopped, perform artificial respiration. Keep person warm and at rest. Treat symptomatically and supportively. Get medical attention immediately.

#### SKIN CONTACT:

##### SULFUR HEXAFLUORIDE:

Acute exposure - Contact with the liquefied gas may cause frostbite with redness, pain and wounds.

Chronic exposure - No data available.

First aid - It is unlikely that emergency treatment will be required. If adverse effects occur, get medical attention. In case of frostbite warm affected skin in warm water at a temperature of 107 °F. If warm water is not available or impractical to use, gently warm affected part in blankets. Encourage victim to exercise affected part while it is being warmed. Allow circulation to return naturally (Matheson Gas, 6th ed.). Get medical attention immediately.

#### EYE CONTACT:

##### SULFUR HEXAFLUORIDE:

Acute exposure - Contact with the liquefied gas may cause frostbite with redness, pain, and blurred vision.

Chronic exposure - No data available.

First aid - It is unlikely that contact with the gas form will require emergency treatment. If contact with liquified or compressed gas occurs, wash with large amounts of warm water until no evidence of chemical remains (approximately 15 - 20 minutes). Get medical attention immediately.

#### INGESTION:

##### SULFUR HEXAFLUORIDE:

Acute exposure - Ingestion of a gas is unlikely.

Chronic exposure - No data available.

First aid - It is unlikely that emergency treatment will be required. If adverse effects occur, treat symptomatically and supportively and get medical attention.

#### ANTIDOTE:

NO SPECIFIC ANTIDOTE. Treat symptomatically and supportively.

---



## REACTIVITY

### REACTIVITY:

Stable under normal temperatures and pressures.

### INCOMPATIBILITIES:

#### SULFUR HEXAFLUORIDE:

DISILANE: Explodes on contact.

### DECOMPOSITION:

Decomposition yields toxic and hazardous fluorine gas and oxides of sulfur.

### POLYMERIZATION:

Hazardous polymerization has not been reported to occur under normal temperatures and pressures.

---

## STORAGE AND DISPOSAL

Observe all Federal, State and Local regulations when storing or disposing of this substance. For assistance, contact the district director of the environmental protection agency.

Store away from incompatible substances

---

## CONDITIONS TO AVOID

Avoid heating to decomposition and contact with or storage with incompatible substances.

---

## SPILL AND LEAK PROCEDURES

### OCCUPATIONAL SPILL:

Stop leak if you can do it without risk. Keep unnecessary people away; Isolate hazard area and deny entry.

---

## PROTECTIVE EQUIPMENT

### VENTILATION:

Provide general dilution ventilation to meet published exposure limits.

### RESPIRATOR:

The following respirators are recommended based on information found in the physical data, toxicity and health effects sections. They are ranked in order from minimum to maximum respiratory protection.

The specific respirator selected must be based on contamination levels found in the work place, must not exceed the working limits of the respirator and be jointly approved by the National Institute for Occupational Safety and Health and the Mine Safety and Health Administration (NIOSH-MSHA).

Any supplied-air respirator operated in pressure-demand or other positive pressure mode.

Any self-contained breathing apparatus.

For firefighting and other immediately dangerous to life or health conditions:

Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode.

Supplied-air respirator with full facepiece and operated in pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.

**CLOTHING:**

Employee must wear appropriate protective (impervious) clothing and equipment to prevent repeated or prolonged skin contact with this substance.

**GLOVES:**

Employee must wear appropriate protective gloves to prevent contact with this substance.

**EYE PROTECTION:**

Employee must wear splash-proof or dust-resistant safety goggles to prevent eye contact with this substance.

**EMERGENCY EYE WASH:** Where there is any possibility that an employee's eyes may be exposed to this substance, the employer should provide an eye wash fountain within the immediate work area for emergency use.

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**AUTHORIZED:** Matheson Gas Products;

**NO DISTRIBUTION EXCEPT AS REQUIRED BY LAW.**

**CREATION DATE:** 01/24/89

**REVISION DATE:** 03/28/90

**-ADDITIONAL INFORMATION-**

\*Matheson makes no warranties, guarantees or representations of any kind or nature with respect to the product or this data, either expressed or implied, and whether arising by law or otherwise, including but not limited to any implied warranty of personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use or reliance upon this data\*

SHELL LUBRICANTS U.K.  
\*\*\*\*\*  
LUBRICANTS HEALTH AND SAFETY DATA SHEET  
\*\*\*\*\*

|                                     |   |
|-------------------------------------|---|
| <b>BRAND NAME</b>                   | Shell Ondina Oil EL   |
| <b>SUPPLIERS NAME &amp; ADDRESS</b> | Shell Oils<br>Cobden House<br>Station Road<br>Cheadle Hulme<br>Stockport<br>Cheshire<br>SK8 5AD |
| <b>CONTACT:</b>                     | Product Technology  |
| <b>TITLE:</b>                       | UOSPL/4   |
| <b>TEL:</b>                         | 061 488 3000  |
| <b>TELEX:</b>                       | 669120  |

**PHYSICAL DATA**  
\*\*\*\*\*

|                         |                                     |                                 |       |
|-------------------------|-------------------------------------|---------------------------------|-------|
| <b>PHYSICAL FORM:</b>   | Liquid                              | <b>DENSITY @ 15 deg C, kg/l</b> | 0.851 |
| <b>pH (CONCENTRATE)</b> |                                     | <b>pH (SOLUTION)</b>            |       |
| <b>ODOUR/COLOUR</b>     | Oily Netural / Colourless           |                                 |       |
| <b>FLASHPOINT</b>       | 140 deg C Min (IP 34 PM Closed Cup) |                                 |       |

**REACTIVITY DATA**  
\*\*\*\*\*

|  |   |
|--|---|
| <b>STABLE :</b>                            | Yes   |
| <b>HAZARDOUS POLYMERIZATION :</b>          | Well not occur  |
| <b>CONDITIONS TO AVOID :</b>               | Strong oxidising agents, extremes of temperature, sources of ignition.    |
| <b>DECOMPOSITION/COMBUSTION PRODUCTS :</b> | Hydrocarbons, oxides of carbon, traces of oxides of nitrogen and sulphur. |
| <b>ADDITIONAL INFORMATION :</b>            |   |

### CHEMICAL COMPOSITION

\*\*\*\*\*

| COMPONENT : | Shell Ondina Oil EL | % WEIGHT |
|-------------|---------------------|----------|
|             |                     |          |

### EMERGENCY FIRST AID

\*\*\*\*\*

REFER TO SHELL PETROLEUM PRODUCTS GUIDE TO HEALTH AND SAFETY

See page 20

### HANDLING PRECAUTIONS

\*\*\*\*\*

HAZARD LABEL REQUIREMENTS

Does not attract any.

**STORAGE :** Store under cover away from direct heat and avoid extremes of temperature. Containers should be kept sealed when not in use.

**NORMAL FIRE EXTINGUISHING MEDIA :** Foam, Dry Powder, Carbon Dioxide, Halon,  
NEVER USE WATER JETS

**SPILLAGE PRECAUTIONS :** Prevent the spread of product and especially its entry into drains/watercourses by the use of sand, earth or other absorbent material. In the event of product reaching public drains/watercourses inform the Local Authority immediately. If possible recover the bulk product. For small and residue of large spillages, absorb the product and remove contaminated absorbent to a safe place for disposal.

**WASTE :** Contaminated bulk and absorbent should be disposed of by a licensed waste contractor. Incineration is preferable to landfill

**RELEVANT LITERATURE :** Control of Pollution Act 1974

The Control of Pollution (Special Waste) Regulations 1980

SI No. 1709

Dept. of Environment 'Waste Management Paper No. 7 Mineral Oil Wastes'.

|                                 |   |  |
|---------------------------------|---|--|
| NEUTRALISING CHEMICALS OR MEDIA | : | None required  |
| STATUTORY NOTIFICATION REQUIRED | : | No   |
| POISONOUS / HARMFUL WASTE       | : | No   |
| ENVIRONMENTAL PRECAUTIONS       | : | Do not allow to enter drainage systems, rivers or waterways. |

#### TOXICITY \*\*\*\*\*

ORAL LD 50 : Greater than 10 mls/kg (rat)

ACUTE EFFECTS : No specific effects

EFFECT UPON EYES : May cause transient irritation of conjunctiva.

EFFECT UPON SKIN : Gross over-exposure may lead to keratosis, dermatitis.

CORROSIVITY : Not corrosive

|               |   |            |   |                               |
|---------------|---|------------|---|-------------------------------|
| SENSITISATION | : | Skin       | ) | Not expected to be sensitiser |
|               | : | Inhalation | ) |                               |

OTHER TOXIC EFFECTS : None known.

VENTILATION REQUIREMENTS : Exposure to oil mists, fumes and vapour should be avoided. Oil mists should be kept to a minimum, preferably well below 5 mg/m<sup>3</sup>

PERSONNEL PROTECTION : Prolonged or repeated contact with the skin should be avoided. Use of impervious PVC gloves desirable. Overalls should be laundered regularly.

#### COMMENTS \*\*\*\*\*

Shell Ondina Oil EL is unlikely to present any significant health and safety hazard when properly used in the recommended application and good standards of industrial and personal hygiene are maintained.

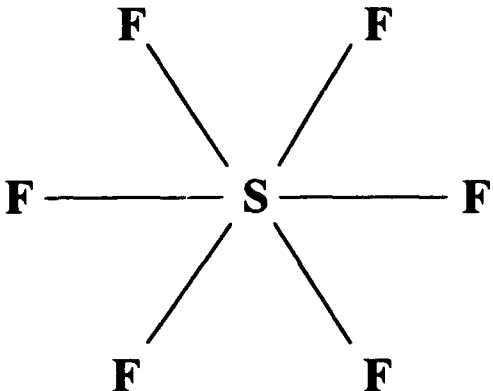
Date : September 1989

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**APPENDIX B**

**CHEMICAL / PHYSICAL / ENVIRONMENTAL INFORMATION ON  
SULFUR HEXAFLUORIDE**

# CHEMICAL AGENT SIMULANT DATA CENTER

|  |  |   |  |
|--|--|---|--|
| Today's Date<br><div style="text-align: center;">09/23/92</div>  |    |   |  |
| Entry Number<br><div style="text-align: center;">602</div>   |  |   |  |
| CRDEC Number<br><div style="text-align: center;">CRDEC-0602</div>  |  |   |  |
| CAS Reg Number<br><div style="text-align: center;">2551-62-4</div>   |  |   |  |
| SULFUR HEXAFLUORIDE  |  |   |  |
| Formula<br><div style="text-align: center;">SF<sub>6</sub></div>   |  | Synonyms<br><div style="text-align: center;">sulfur fluoride<br/>SF<sub>6</sub></div> |  |
| Molecular Weight<br><div style="text-align: center;">146.054</div>   | Vapor Density<br><div style="text-align: center;">5.04</div>                         |   | Molar Volume<br><div style="text-align: center;">77.7 @ mp</div> |
| WLN<br><div style="text-align: center;">FSFFFFF</div>  | Melting Point (°C)<br><div style="text-align: center;">-50.8    Ref 42, 76, 78</div> |   | Calc Molar Ref   |
| Vapor Pressure (torr)<br>2.75629E6 @ 20°C liq    Ref 76<br>1.0 @ -133°C subl    Ref 78<br>40.0 @ -102°C subl    Ref 78<br>100.0 @ -91°C subl    Ref 78<br>400.0 @ -73°C subl    Ref 78 |  |   | Viscosity (cp)   |
| Density (gm/cc)<br>1.88 @ -50.8°C liq    Ref 42, 76, 78<br>6.602 g/l gas    Ref 52, 78   |  |   | Volatility (mg/m <sup>3</sup> )                                  |
| Boiling Point (°C)<br>-63.8 @ 760 subl    Ref 76, 78   |  |   | Diffusivity (cm <sup>2</sup> /sec)                               |
| Refractive Index   |  |   | Refractive Index   |



|                               |   |              |
|-------------------------------|---|--------------|
| Surface Tension (dynes/cm)    | Heat Capacity (cal/gm °C)                     |              |
| 3.28 @ 20°C Ref 76            | 0.159 Ref 76                                  |              |
| Heat of Vaporization (cal/gm) | Specific Heat (cal/gm)                        |              |
| 27.93 @ -63.8°C Ref 76        |   |              |
| Heat of Combustion (cal/gm)   | Decomp Temp (°C)                              | Oxygen Index |
|                               |   |              |
| Heat of Fusion (cal/gm)       | Flash Point (°C)                              |              |
|                               |   |              |
| Heat of Formation (cal/gm)    | Autoignition Temp (°C)                        |              |
|                               |   |              |
| Energy to Vaporize (cal/gm)   | Dielectric Constant                           |              |
|                               |   |              |
| Critical Temp (°C)            | Dipole Moment (debyes)                        |              |
| 45.6 Ref 42, 76               | 0.0 Ref 76                                    |              |
| Critical Pressure (atm)       | Hygroscopicity                                |              |
| 37.11 Ref 76                  |   |              |
| Critical Volume (cc/mole)     | O/W Partition Coefficient (Log <sub>p</sub> ) |              |
|                               | 1.68 Ref 72                                   |              |
| Critical Density (gm/cc)      | Solubility Parameter (H)                      |              |
| 0.524 Ref 76                  |   |              |
| Water Solubility              | Toxicity                                      |              |
| slight Ref 42, 78             | TLV = 6000 mg/m <sup>3</sup>                  |              |

|  |                                 |
|--|---------------------------------|
| <b>Hydrolyses Rate</b>   | <b>Solubility Value (gm/ml)</b> |
| <b>Industrial Application</b><br><br>in electric circuit interrupters.<br>in electronic ultrahigh frequency piping.  |                                 |
| <b>Chemical Reactivity</b>   |                                 |
| <b>Simulant Application</b><br><br>proposed as vapor tracer sim by CAN for threat / hazard assessment trials<br>proposed as vapor tracer sim by UK for individual protection trials<br>used as vapor tracer sim by US in collective protection trials<br>used as vapor tracer sim by US in detection trialling |                                 |
| <b>Comments</b>  |                                 |

### References

- 42 Windholz, Martha, Editor. The Merck Index. 9th Edition. Merck & Co., Inc., Rahway, NJ. 1976.
- 52 Cohen, L., Rodon, G. W. Properties of Polymer Solutions For Use in VX Sprays. CRDLR 3069. 1961/04.
- 72 Issue 22 of Log P and Parameter Data Base. Comtex Scientific Corp., 850 Third Ave., N.Y., N.Y., 10022. 1983/01 or late.
- 76 Dean, John A., Editor . Lange's Handbook of Chemistry. 12th Edition. McGraw-Hill Book Co., N.Y. 1979.
- 78 Weast, Robert C., Editor. CRC Handbook of Chemistry and Physics. 64th Edition. CRC Press Inc. 1984

# Fate and Effects CRDEC Data Management System 23-SEP-92

## Sulfur hexafluoride

CAS Reg No.: 2551-62-4

RTECS No.: WS4900000

CRDEC No.: 85097

Formula: SF<sub>6</sub>

### Synonyms:

UN 1080 (DOT)  
SULFUR HEXAFLUORIDE (ACGIH, DOT)  
SULFUR HEXAFLUORIDE  
SULFUR FLUORIDE  
HEXAFLUORURE DE SOUFRE (FRENCH)

| Property                             | Value           | Condition  | References |
|--------------------------------------|-----------------|------------|------------|
| Solubility (H <sub>2</sub> O) (Calc) | 31.000 mg/l     |            | 26         |
| Solubility (H <sub>2</sub> O)        | 31.000 mg/l (Ca |            | 26         |
| Specific gravity                     | 1.880 g/cc      | -50.000 °C | 497        |
| Specific gravity                     | 1.336 g/cc      |            | 506        |
| Vapor Specific gravity               | 6.089 g/l       |            | 506        |
| Vapor Specific gravity               | 6.500 g/l       |            | 26         |
| Molecular weight                     | 146.070         |            | 497        |
| Melting point                        | -50.800 °C      |            | 57         |

### DESCRIPTORS:

Sulfur hexafluoride is a nonflammable, colorless, odorless, gas. (497)

### CHEMICAL AND PHYSICAL PROPERTIES:

### MILITARY APPLICATION:

#### THERAPEUTIC USES

The intraocular injection of sulfur hexafluoride appears to be useful contribution to the surgical treatment of superior bullous hemi-retinal detachment, allowing effective and durable internal tamponade, while avoiding prolonged bed rest.

The investigators devised a new therapeutic method which consisted in injecting sulfur hexafluoride into the postpneumonectomy pleural space so as to maintain the chest cavity. Gas injection at intervals of 6 months can maintain a clear pleural space with neither retention of pleural effusion nor deformity of the thorax.

### INDUSTRIAL APPLICATION:

Sulfur Hexafluoride is used as a gaseous insulator for guides (507). It has been widely used as a tracer gas for both indoor and outdoor source dissemination experiments as well as for measuring gas exchange coefficients in lakes (508, 509, 510).

## ENVIRONMENTAL LAWS AND REGULATIONS:

Sulfur hexafluoride is not listed in the TSCA inventory. The substance is not listed as a hazardous material by DOT, as a hazardous waste under the RCRA, or as a hazardous substance under the CERCLA or the FWPCA.

## TOXICOLOGY:

Mutagenicity:  
Repro Effects:  
Tumorigenicity:  
Ecotoxicity:  
Human Exposure: Time weighted avg (TWA) 1000 ppm, 6000 mg/m<sup>3</sup>; short term exposure limit (stel) 1250 ppm, 7500 mg/m<sup>3</sup> (1983-84).

## TOXIC HAZARD RATING

Acute Systemic: Inhalation 1. 1 = slight: causes readily reversible changes which disappear after end of exposure.

## POISONING POTENTIAL

It has not been possible to establish its experimental toxicity clinically (481). Essentially nontoxic gas. The chief hazard, as with other inert gases, would seem to be asphyxiation as a result of the displacement of air.

| RATE        | SPECIES | DOSE       | EFFECT (Ref) |
|-------------|---------|------------|--------------|
| Intravenous | Rabbits | 5790 mg/kg | LD50         |

Fifty rats exposed to sulfur hexafluoride atmosphere (80% with 20% oxygen for periods of from 16-24 hr) showed no effects from the exposure.

## CHEMICAL REACTIVITY:

## ENVIRONMENTAL FATE:

### ENVIRONMENTAL FATE / EXPOSURE - ENV

Sulfur hexafluoride may be released to the environment during its production, storage, transportation, and use as a gaseous insulator for electrical equipment and a tracer gas for source dessimation and gas exchange studies. It is an extremely inert gas and would not be expected to degrade under environmental conditions. If released on land, sulfur hexafluoride will be lost primarily by volatilization. It does not absorb appreciably to soil and therefore, may leach into the ground water. If released in water, it will be lost by volatilization. Its half-life in a model river is estimated to be 3.5 hr. In the atmosphere, it will be transported to the ground by wet and dry deposition. Sulfur hexafluoride is a very dense gas so it will mainly reside in the lowest layers of air. Exposure will be primarily occupational.

### TERRESTRIAL FATE:

If released on soil, sulfur hexafluoride will be lost primarily by volatilization. It does not adsorb to soil and may also transport to the subsoil and ground water. Degradation in soil should not be significant.

#### **AQUATIC FATE:**

If released into water, sulfur hexafluoride would be lost primarily by volatilization. Its estimated volatilization half-life from a model river 1 m deep having a 1 m/sec current with a 3 m/sec wind is 3.5 hr. The volatilization would be controlled by resistance in the liquid phase indicating that the rate of volatilization is more influenced by water current than wind speed. Adsorption to sediment and particulate matter in the water column should be negligible.

#### **ATMOSPHERIC FATE:**

Sulfur hexafluoride is one of the heaviest known gases with a vapor density approximately five times that of air (497). Therefore, if released in the atmosphere, it will tend to remain close to the ground and be transported to earth by wet and dry deposition. It is inert and should not degrade.

#### **ABIOTIC DEGRADATION - ABIO**

Sulfur Hexafluoride is very resistant to attack and extreme conditions are required (511). For example it resists molten KOH and steam at 500°C (511). Sulfur hexafluoride is inert at room temperature and atmospheric pressure (506). Its high resistance has been ascribed to its high S-F bond strength, coordinate saturation, steric hindrance, and nonpolarity (511). While hydrolysis is energetically favorable, the fluorine groups effectively shield the sulfur atom and impede this reaction (506).

#### **BIOCONCENTRATION - BIOC**

Using the water solubility of 31 mg/l (508), one can estimate a bioconcentration factor (BCF) of 89 for sulfur hexafluoride using a recommended regression equation (512). Therefore sulfur hexafluoride would not be expected to bioconcentrate appreciably in fish and aquatic organisms.

#### **SOIL ADSORPTION / MOBILITY - KOC**

The adsorption of sulfur hexafluoride was studied in four soils that differed markedly in pH, texture, and organic carbon content by injecting 100 ppm of the gas into bottles containing 5 g soil and following the concentration of the sulfur hexafluoride in the air for 15 days (513). The experiments were conducted using both air-dried soils and soils moistened to fifty percent of their water-holding capacity. None of the soils tested adsorbed any sulfur hexafluoride. Sulfur hexafluoride's lack of adsorptivity is one characteristic that makes it an ideal tracer gas.

#### **VOLATILIZATION FROM WATER / SOIL - VWS**

The Henry's Law Constant for sulfur hexafluoride is  $4.52 \text{ atm-m}^3/\text{mole}$  at 25°C (508). Using this Henry's Law Constant, one can estimate that sulfur hexafluoride's volatilization half-life from a model river 1 m deep having a 1 m/sec current with a 3 m/sec wind would be a 3.5 hr (512). The volatilization would be controlled by resistance in the liquid phase. The half-life in a pond or lake would be much longer. Experiments in which volatilization of sulfur hexafluoride from a shower was determined, showed the amount of sulfur hexafluoride volatilized was much less than would be predicted from the Henry's Law Constant (508). In these cases, equilibrium was not attained and the rate of volatilization was determined by mass-transport across the air-water interface.

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